# CONSTRUCTION SURVEYING

## 63-04.0100 GENERAL

Construction surveying, as with most types of surveying, has evolved tremendously over the past thirty years. From the transit, chain and plumb bob to the theodolite, EDM and prism pole to the total station to the robotic instruments to the present GPS (Global Positioning System) equipment which has lead to a new era in construction surveying and coined a new term, "stakeless surveying". Most roadway contractors now have their earth moving equipment, dozers, graders, etc. outfitted with GPS allowing their operators to build a road by watching a monitor instead of being guided by a forest of stakes in the ground. While conventional surveying methods will still apply, the Department and its personnel must also evolve in our techniques and practices in construction surveying.

The Standard Specifications for Road and Bridge Construction Manual's Section 201-Staking specifies the Department/Contractor responsibility in regard to staking on our construction projects. The following information suggests proven techniques and procedures for the various types of construction staking and measurements.

## 63-04.0200 FIELD BOOKS

All field notes will be recorded in standard bound field notebooks. These books are permanent source documents and may serve as a legal reference. The notes shall be organized and as neat as possible with figures and measurements sufficiently clear to provide for easy reading and checking of computations and/or quantities. Field books should be identified on the cover by the PCN No., County, Route No., and Road Name. The Project Engineer's name and address and phone number should be on the back of the front cover in case of loss. All pages should be numbered and the weather, dates, and personnel shown at the beginning of each day's notes.

## 63-04.300 CHECKING PLANS

Plans should be checked and field books and/or electronic data prepared prior to beginning construction staking. ***<u>Plans should never be taken for granted.</u>*** Centerline geometries should be recalculated and the necessary data recorded. Plan grades should be checked. Any errors or omissions should be corrected and entered in the Project Engineer's office plans and field books and, ultimately, in the As-Built Plans. Any appreciable error should be immediately reviewed with the District Construction Office since Design, and as well Right of Way may be affected. Bridge grades should be checked against road grades to be sure of proper vertical alignment. Bridge plans should particularly be studied for orientation. Vertical clearances should be checked as well as the dimensions of footings, piers, rockers, beams and deck so that they are in agreement with footing and deck elevations. Furthermore, plans should be field checked for omissions or topographical changes that may have occurred after the location survey so that recommendations can be prepared and the contract status revised prior to the commencement of work.

Electronic Data Controllers (ex. Sokkia SDR33 and Trimble TSCII) can be used in conjunction with or as an alternative to establishing field books. Electronic coordinate files can be created and uploaded to the data controllers. The information should be printed and bound to serve as field books and as a reference in the field. Various Stake Road Programs (see example in Exhibit No. 64-4-18) found in the Data Controller can be used to stake fieldwork by entering horizontal, vertical, and roadway template information directly from the plans. The Data Controller can then generate and/or stake out information based on proposed Station, Offsets, & Elevations. Uploading proposed roadway alignments to the data controller should be performed before field work commences. Manual checks should be performed to verify data collector output for proposed alignment coordinates, elevations, and templates.

## 63-04.0400 PROJECT CONTROL AND STAKEOUT

**.0410 Control Points** – These points are shown in the roadway plans, usually on the page titled Reference Sheet, and are monuments, either disks set in concrete or iron pins with caps, that have both horizontal (coordinate) and vertical (elevation) values assigned to them and are used by the Department and the contractor for all surveying duties required to complete the project.

These points are derived from high accuracy reference networks such as the National Geodetic Survey, the U.S. Geological Survey and the KYHARN.

These points must be verified for accuracy prior to construction either by the traverse method or from GPS observations.

**.0420 Benchmarks** – These marks are also shown on the plans and normally only have vertical (elevation) values assigned to them. They are usually nails or spikes in trees or power poles and are normally referred to as Permanent Benchmarks (B.M.'s) as opposed to new benchmarks established by the Project Engineer which are referred to as Temporary Benchmarks (T.B.M.'s). Permanent benchmarks are numbered in sequence with the project stationing, for example, B.M. No. 19, B.M. No. 20, etc. Temporary benchmarks are assigned the same number as the permanent benchmark from which it was established with an alphabetical suffix as identification, for example, T.B.M. No. 19A, T.B.M. No. 20A and T.B.M. No. 20B.

All benchmarks should be established where they will give the easiest access to future engineering work and yet be as safe as possible from the construction work. A permanent or temporary benchmark should always be located adjacent to a proposed culvert or bridge structure. The description, location, and elevation of each benchmark should be accurately noted and should become a part of the permanent record plans. Copies should be placed in all field books for convenience of field personnel.

**.0421 Check Level** - Check levels should be run to establish the accuracy of the benchmarks as noted on the plans. This work needs to be done as soon as possible and may be performed in conjunction with the verification of the project control points if sufficient personnel are available. In addition to checking the plan benchmarks, new or temporary benchmarks are established throughout the project in strategic locations. All future accuracy of highway grades on the project are dependent on accurate benchmarks so these check levels must be done with care.

A "Level" field book should be set up which will ultimately contain all permanent and temporary benchmarks, their elevations, locations, and descriptions. All check levels and any subsequent checking should also be included if possible. Refer to Exhibits 63-4-3 & 4.

**.0422 Structures** - Either one or more benchmarks should be established conveniently close to each culvert and bridge on the project. These benchmarks should be located so that they can be read with one setup of the level if the terrain permits. Structures spanning wide streams may have to have several benchmarks, but they should be checked closely. It is good construction practice to use the same benchmark through the entire construction period of the structure.

**.0423 Pipe** - Each pipe and particularly the large pipe should have a benchmark close enough to be read with one setup if possible.

**.0430 Right-of-Way and Temporary Easements –** While it's the contractors responsibility to stakeout these points, the Project engineer and/or his inspectors must have the ability to check these points throughout the project as required. Sufficient stakes should be set at any location with a property or encroachment problem to enable all parties to get a clear understanding of the right-of-way location. Stakes should be marked as right-of-way and or temporary easement and noted with the station number and offset width.

**.0440 Encroachment** - At this stage in the stakeout work, all encroachments should be carefully noted and the necessary action taken to obtain their early removal. Property owners should be advised to remove fences and buildings from within the limits of the right-of-way in advance of the contractor's clearing and grubbing operations. The Project Engineer should advise his inspectors and field forces to be alert at all times for new encroachments which infringe on the established right-of-way. Any indication of such activity must be checked immediately and if found to be an encroachment, necessary steps taken to cause its removal. There can be no excuse for an encroachment to exist within the limits of the right-of-way and not be discovered until time of final inspection. With few exceptions, adjacent property owners will cooperate in keeping the right-of-way clear of encroachments if they are properly advised of the necessity and if the right-of-way is properly marked

The inspector on the project should be in a position to so advise the property owners as well as determine the right-of-way limits. No field employee can authorize a new encroachment or permit an old encroachment to remain within the limits of the right-of-way.

## 63-04.0500 NGS / USGS SURVEY MARKERS

During the past century and a half, the National Geodetic Survey (formerly U.S. Coast and Geodetic Survey) and the U.S. Geological Survey, both Federal entities, has been determining with great accuracy the latitude and longitude, state plane coordinates and/or elevation of thousands of locations throughout the United States. At most points, a bronze disk is embedded in concrete or bedrock while some later marks consist of a steel rod driven to solid resistance encased in a pipe with a protective cap. These marks are used by engineers and surveyors for various public and private projects.

Other survey marks to watch out for are U.S. Army Corps of Engineers disks, found mostly around lakes and streams predominately in eastern Kentucky and TVA (Tennessee Valley Authority) disks, found in western Kentucky.

Preservations of the survey disks are vitally important. At one time, there were upwards of 20,000 such marks in Kentucky but, through the years, this number has dwindled considerably. The Project Engineer should be sure that all members of his crew are familiar with these markers (Refer to Exhibit 63-4-6) and the following instructions.

1. Never remove or disturb a survey marker.
2. If you see a survey mark, which appears in danger of destruction or damage by erosion, construction, or other causes, please takes appropriate steps to preserve it.
3. If it becomes necessary, in the course of construction, to relocate a survey mark whether belonging to NGS/USGS or not, place an immediate call to the Division of Construction, Phone No. 502-564-4780 for assistance. See instructions in sub-section 63-04.1442 of this chapter for additional information.

## 63-04.0600 BORROW SITE CROSS-SECTIONS

The area from which borrow is to be removed must be determined and plainly staked by the contractor before cross sectioning can start. The volume of material moved will be measured in the original position by the cross-section, average end-area method.

If the borrow site lies adjacent to construction, the regular road cross-section can be extended to include the area involved. However, care must be taken to differentiate between roadway excavation and borrow excavation if they coincide.

If the borrow site is located away from the construction area, two or more control points must be established to provide a basis for cross-sections. The control points should fall well outside any possible operation of the contractor.

A sketch of the layout of the borrow site will be shown on the first page of the notes. The sketch should include control points, stationing, borrow limits, a description of the location of the site usually referenced to the roadway station numbers, and all other pertinent information to enable any person, unfamiliar with the project, to re-establish and carry on with the work. Should a field book sketch prove too crowded, an alternate method is to provide this information on cross-section paper with adequate referral notes in the field book.

## 63-04.0700 LOCATING AND STAKING PIPE CULVERTS

When staking pipe culverts, the plan lengths and flow line elevation of the pipe should first be checked in the field and, if necessary, adjusted to fit field conditions. Flow line elevations of a pipe culvert will normally be based on the elevations of the natural flow line of the channel.

Pipe culverts are staked by setting a working hub and tack on the centerline of the pipe at an offset distance from each end of the pipe sufficiently removed from the work zone but also close enough to be readily accessible to the pipe laying crew. It is good insurance to set a reference hub and tack further out from each end of pipe in as safe a location as possible to simplify restoration of the working hub should the occasion arise. Elevations are taken on the top of the hubs and a guard stake will be marked with the centerline station number, measured offset distance, size of pipe, and the cut or fill from hub to flow line at the referenced end of pipe. Additional long guard stakes should be flagged (with the designated color for pipe) and utilized to protect the hubs and information stakes.

Data Controllers can assist the field operation of setting out centerline of pipe and box culverts by using the ‘Set out line’ program found in the surveying menu. It gives the field party the capability of staking the centerline of pipe from a point with known coordinates and along a specified bearing. It gives you the flexibility of staking at any distance along the centerline that you desire. It has the capability of setting an offset and grade if needed. This program is also useful for laying out of bridge abutments and piers. Box culvert footers can be entered as a horizontal and vertical alignment along with a template representing the width of the culvert footer. This provides the ability to collect elevations (original ground, top of rock, plan grade, etc.) at any point of the along the footer alignment and the data controller calculates cut or fill to finished grade. Refer to the manual that comes with the respective data controller for specific information for the use of these programs.

Pipe culverts are to be staked by the contractor. ***It is good practice of department personnel to verify the accuracy of the contractors' work.*** A permanent record of the entire procedure and data should be kept in the project pipe book.

## 63-04.0800 CHECKING ORIGINAL CROSS-SECTIONS

The Project Engineer should determine, by observation of the conditions in the field and by check sections, if necessary, the need for retaking and/or extending the original cross-sections or making additions to the original sections in such amount as to adequately establish original ground elevations.

The Project Engineer should be extremely careful when he has original cross-sections developed from aerial photography, particularly when steep side hill cuts are involved. Original cross-sections developed from aerial photographs are normally of sufficient accuracy for construction, however when a Project Engineer encounters this type project, he should take sufficient check sections to satisfy himself as to the accuracy of the originals.

## 63-04.0900 SLIDES

When slides occur that involves failures in original ground behind the cut slope stakes and/or in the cut slope, the Project Engineer has a problem that requires immediate action.

If it appears that the slide or repair of the slide will disturb original ground beyond the limits of the original cross-sections, he should immediately put the survey party to work to extend the cross-sections. The limits of these sections should include at least 100 feet on each side of the slide area or more if necessary and extend well back of the slide to stable ground, if possible. Should it be necessary to extend the sections off the right-of-way, the Project Engineer should get the property owners permission in writing. The extended sections should be plotted right after they are taken on the same scale as the originals. It is also important that the Project Engineer notify the District Construction Office of the slide as soon as possible. He should be able to brief them on the location (sta. nos.), the extent of the slide, his estimate of how it will effect the contractor's operation and any action that he had initiated.

Slides invariably mean an increase in construction cost and, depending on their nature and extent can involve re-design, construction revisions, acquiring additional right-of-way and considerable additional roadway excavation. All these operations require time and result in delays in completing the project. At the discretion of the Project Engineer, material removed can be used as borrow excavation for a roadway fill. The Project Engineer should recognize this and make every effort to expedite his work and cooperate with all involved parties. He should get his sections taken and plotted as soon as possible since all subsequent actions and decisions depend on their availability. He should also afford the Division of Materials Geotechnical Section any staking or aid they may require if they are consulted on the problem and in general stay on top of the situation.

## 63-04.1000 SLOPE STAKES

Set by the contractor, slope stakes are the control points to the right and left of roadway centerline at points where the finished side slopes will intersect the surface of the original ground. These stakes are for the guidance of the contractor in constructing cuts and fills.

As a general rule, slope stakes are referenced to shoulder grade for fills and either shoulder grade or ditch grade in cuts. The front of the stake (toward centerline) should indicate either cut or fill, as the case may be, the amount of cut or fill based on the vertical measurement from the shoulder or ditch grade to the slope stake, the horizontal measurement from the slope stake to the ditch line or shoulder point and the slope. The back of the stake will show the station number. If it becomes necessary to offset the stake back from it's correct location, the offset distance should also be shown on the front. See Exhibit 63-4-9.

Slope stakes should not be set until all the clearing and grubbing is finished in their vicinity. They should be adequately guarded with laths, which should be flagged with the appropriate color for slope stakes.

If contract staking is specified, it the responsibility of the contractor to keep a slope stake field books and should to be submitted to the Project Engineer to include with the final estimate.

The procedure for setting slope stakes may be found in any good surveying textbook.

## 63-04.1100 GRADE STAKES (BLUETOPS)

Fine grade control is necessary to aid the contractor in establishing typical subgrade section. This fine grade control is established by setting hubs (referred to as bluetops) every fifty feet to the typical subgrade section. These bluetops are set to the hundredth in elevation and are located left and right of pavement centerline, usually at the edge of pavement.

It may be necessary in the case of passing lanes or wide curb and gutter sections to set additional bluetops to aid in controlling the fine grade.

All grades for bluetops shall be computed to the nearest 0.01-foot of the required grade. Bluetops are normally set for the top of subgrade and the top of the aggregate base material. A lath should be driven at each bluetop to serve as a guard stake and should show the station number designation.

Bluetops derive their name from the practice of "Bluing" the top of the grade stakes or hubs. Bluetops are generally located at the opposing edges of pavement and at centerline of the lane, however, these locations may be modified to fit each particular contractor's operation. The use of autograde machines on larger projects requires a completely different system for setting grade stakes. The stake road program available in most data controllers may be used to check bluetops. The proposed horizontal & vertical alignments along with the roadway template must be loaded into the data controller. This process creates a 3D wireframe model of the proposed roadway allowing the field crew to check cut or fill at any location along the proposed alignment. All data controller calculations should be verified manually before using this technique.

The Project Engineer should review the operation for setting bluetops thoroughly with the contractor and be sure everybody understands the procedure. If contract staking is involved the Project Engineer needs to approve the procedure utilized and perform routine checks as the job progresses. Also, if contract staking is specified, it the responsibility of the contractor to keep a grade field books and they are to be submitted to the Project Engineer to include with the final estimate.

## 63-04.1200 CONTRACT STAKING

When contract staking is listed as a bid item, the contractor shall furnish all necessary personnel and equipment to provide a construction staking party as provided in Section 201.01-05 of the Standard Specifications.

In accordance with the Standard Specifications, the contractor's staking party shall be under the general supervision of a Licensed Professional Engineer or Licensed Land Surveyor. The Project Engineer should make sufficient checks of the contractor's staking to determine that the methods and procedures used are capable of producing the desired results.

At completion of the project, the contractor should submit all field books to the Project Engineer for review and to include in with the Project Engineers' file. The Standard Specifications specify the Department's responsibilities with respect to project staking when Contract Staking is a bid item.

## 63-04.1300 PAY ESTIMATE

**.1310 Roadway Excavation** - Roadway excavation must be calculated biweekly for purpose of pay estimates. The preferred method for estimating roadway excavation quantities for biweekly estimates is as follows:

Estimate a quantity of material based on information printed for the type and size of equipment being used and swell factors for material being moved to determine a close approximation of material moved by each unit. Keep an accurate load count of trips made with the equipment used each day and verify it matches the count turned into the foreman/superintendent.

Periodically, field measurements must be made to verify that the estimated roadway excavation quantities accurately depict the quantity of material that has been removed. To accomplish this the Project Engineer should:

A. Take abbreviated cross-sections and/or run a profile of sufficient magnitude to establish within reasonable accuracy the elevation(s) of undistributed materials in all significant roadway cuts.

    1. All data should be kept in a bound field book used expressly for this purpose or the Electronic Field Book. The Electronic Field Book data should be printed out kept in a bound notebook or file.
    2. Be sure to note the date that the field measurements are made to compare the quantity of roadway excavation estimated by load counts up to that date.

B. Plot the data thus obtained on the office cross-section sheets and calculate the quantity of material excavated over the applicable pay period. Reference the cross-sections by date and keep a record of the calculations. This may be done on the cross-sections sheets, space permitting.

C. Reconcile the calculated quantities with previously estimated quantities and enter the corrected quantity in the Item Quantity Record.

**.1320 Embankment-In-Place** - When embankment-in-place is a bid item, the Project Engineer should use methods similar to those detailed under roadway excavation for the purpose of biweekly pay estimates and also field measurements to verify estimated quantities. The difference being that the field measurement should be made on the roadway embankment instead of roadway excavation. Then proceed much the same as detailed under roadway excavation and part (B) under borrow materials (below) except that swell or shrinkage need not be considered.

**.1330 Borrow Material -** Borrow excavation should be calculated periodically or at the end of borrowing operations for the purpose of verifying accuracy of roadway embankment estimates or field measurements of roadway embankments. To accomplish this the Project Engineer should:

A. The Project Engineer must plot the original borrow pit cross-sections.

1. The original sections should be plotted on reproducible paper.
2. It is preferable to use copies of the original sections for monthly estimate purposes and retain the originals for the final cross-sections.
3. It is recommended the baseline be referenced in some manner to the centerline of mainline or approaches.

B. Should the borrow pit prove to be so irregular as to make it difficult to obtain accurate quantities, an alternate procedure would be to take the cross-sections or profiles on the embankment(s) and utilize the office blueprint plans much the same as detailed under roadway excavation. The shrinkage or swell factor must be considered with this method.

Special excavation, when included as a bid item, will be considered independent of the embankment-in-place.

## 63-04.1400 STAKING STRUCTURES

**.1410 General** – Here again, this is the contractors responsibility but the Project Engineer and his employees must have the ability to check their work. The following sections are for reference.

**.1411 Field books/Notebooks** - The field books/notebooks for structures should be prepared in advance and all necessary data placed in the book so it will be available when starting staking. All information placed in a field book pertaining to a particular structure should be together. It is preferable that the survey party chief be assigned this responsibility since he will gain an insight into the peculiarities of the particular structure being staked.

All sketches in field books should be neat and drawn with a straightedge. A certain amount of basic information pertaining to the structure or portion of the structure under consideration should be shown. The information should include, but not necessarily be limited to, the outer dimensions of the structure, the flow line elevation or other pertinent grades, the structure excavation limits and skew, if applicable. Any grade changes or other design revisions such as the raising or lowering of a culvert flow line, that involve changes from the original plans should be noted.

Prior to staking any structure, the plan dimensions and layout should be checked for errors. Normally they are correct but do not take for granted that errors are never made on the plans.

**.1412 The Project Engineer** - The Project Engineer should never lose sight of the fact that every structure, regardless of how big it is or complicated to build, is simply a component part of the highway and must fit into the overall project. No culvert or bridge should be staked without being absolutely sure it fits the survey centerline and approach grade controls.

The Project Engineer should always be sure that the contractor's supervisory personnel are thoroughly briefed on the staking procedure. A bridge layout should be reviewed in the field with the foreman or man in charge of building the bridge. Layout procedures vary in different parts of the country and a wrong assumption can be disastrous on what should have been an otherwise excellent job. The structure inspector should also be thoroughly familiar with the layout. If possible, the inspector should be involved in the actual layout work, particularly if the structure is rather complicated.

**.1420 Reinforced Concrete Box Culverts** -

**.1421 Field Book/Notebook** - Each culvert should occupy separate pages or sections of the field book/notebook. Sufficient pages must be allowed for layout of the culvert and the necessary structure excavation shots, both original and final, and any necessary computations. Do not crowd the information. If structure excavation, concrete, steel, or any other quantity is calculated from cross-section sheets, the data in the field book must be cross-referenced.

**.1422 Staking** - In the staking of reinforced concrete box culverts, lines representing centerline of the culvert, front or outside face of the parapets, and the front face of each wing should be established. This work must be done with a total station or a similar instrument of comparable accuracy. The establishing or re-establishing the wing lines with a carpenter's square is not to be permitted. See Exhibit No. 63-4-13. Each line should be referenced with a minimum of at least three hubs w/tack and applicable informational guard stakes. Laths decorated with the appropriately colored ribbon for culvert stakes should be utilized to protect the hubs from heavy equipment. Each reference hub should be placed in such a position as to be outside the construction limits.

Box culvert footers can be entered as a horizontal and vertical alignment along with a template representing the width of the culvert footer. This provides the ability to collect elevations (original ground, top of rock, plan grade, etc.) at any point of the along the footer alignment and the data controller calculates cut or fill to finished grade. Refer to the manual that comes with the respective data controller for specific information for the use of these programs.

A benchmark should be established near the culvert location, but out of the construction zone, to use in establishing elevations and setting grades. It is very important that the level person always checks back in on this benchmark.

The inlet and outlet flow line elevations designated on the plans are the flow line elevations on the centerline of the culvert at the ends of the culvert. When the culvert is skewed to the roadway, flow line grades must be calculated for points where barrel walls and wing walls intersect. An effort should be made to set up on one end of the culvert centerline and align the entire length of the structure.

**.1423 Field Check** - Any discrepancies in either alignment or grade should be brought to the attention of the District Construction Office as soon as possible and certainly before the contractor orders the reinforcing steel or begins work.

**.1424 Excavation Quantities** - Preparation should be made to take the necessary structure excavation shots either at the same time the culvert is laid out or shortly thereafter. The Project Engineer should review the Culvert plans closely to determine if there are any special requirements or drawings which may be included, that will affect the procedure. For example, some culvert plans may stipulate roadway excavation for the culvert barrel or may change the outside limits for structure excavation from that normally required by the Standard Specifications (18” outside of ‘neat lines’). Requirements of this nature, if included in the structure plans, will materially affect the excavation quantities and should be accounted for before beginning this operation.

Examples of procedures to be utilized in taking structure excavation shots and roadway excavation shots, if necessary, are covered in Exhibit 63-4-10 (Sheets 1 & 2).

An example of structure excavation shots in a field book is covered in Exhibit 63-4-11.

**.1425 Contract Staking -** When "Contract Staking" is included in the contract, the contractor bears full responsibility for culvert staking. The Project Engineer still has to make his alignment and grade check as discussed previously under "Field Checks" and is also responsible for the structure excavation quantities. The Project Engineer should check the centerline point, the skew angle, and the length as staked. Any discrepancy should be noted in the diary and brought to the contractor's attention. No attempt should be made by Department personnel to correct the contractor's stakes. If the discrepancy is serious, follow-up checks should be made and, certainly, no concrete should be placed until the discrepancy is resolved.

**.1426 Foundation Preparation and Backfill –** Refer to Specification 603 of the 2000 Standard Specifications for Road and Bridge Construction. When staking a bridge on a project, the engineer and/or his inspector should review project plans and documentation to determine the extent of staking necessary. The pay item of Foundation Preparation is a lump sum item that could and does include a number of construction operations. No staking is necessary for common excavation if the 'Foundation Preparation' bid item is listed. Solid rock excavation remains as a pay item and measurement of such should be accomplished. Any undercutting below plan footing elevation due to poor soil or rock should also be measured for payment.

**.1430 Bridges (General) -** Bridges come in all shapes and sizes and it is difficult, if not impossible, to prescribe staking procedures to fit all possible situations. The information presented herein is directed primarily at the basic bridge layout and checking. The Project Engineer must use acceptable surveying procedures as established in recognized surveying text books in doing the work.

Field books should be prepared essentially the same as explained previously under "General Information" and "Culverts". When precise work is done all calculations and pertinent data should be included. As mentioned previously, it is preferable to have all information pertaining to a particular structure together in a field book. In the case of bridges, this not only means the layout work but structure excavation, "X" dimensions, deck elevations, handrail data, etc., so it may be necessary to leave considerable space. Depending on the size of the bridge, an entire field book may be utilized on a single structure.

**.1431 Staking** - The station number shown on the bridge plans is normally the station at the center of the bridge.

Two points on centerline of survey at each end of the bridge should be established as a control for the centerline of the bridge. These points should be well past the end of the bridge, preferably on high ground that will not be disturbed by the construction operations. These points should be properly referenced so they can be re-established if necessary.

In staking a bridge on a tangent, it is important to align the centerline by looking direct with the transit through all points. If it is not possible to do this, double centering should be performed.

The station of one of the points should be determined and this point used as a control point for locating the piers and abutments.

The working line of the abutment or end bent (this may be the centerline of bearing or some other designated line) and the working line (generally the centerline) of each pier should be carefully established. The working lines should then be referenced with a minimum of three tacked hubs on either side of each pier, bent, or abutment. These points should be well clear of the construction operations. They should be identified with stakes on which the centerline station number, the offset distance (accurately measured) of the particular hub from centerline and the component part of the bridge such as Pier No. 2, End Bent No. 1, etc. should be written with water-proof marking pen or keel. The hubs and stakes should be well guarded by laths, which should be flagged with the appropriate bridge color. Particular attention should be paid to the location of the hubs so they will be readily accessible for future checking of the structure as work progresses. This procedure would lend itself to checking of the bridge layout exceptionally well, particularly if the first two lines of offset hubs can be located parallel to the bridge centerline. The span lengths and skew can then be readily checked. An example of a bridge layout similar to this is included in Exhibit 63-4-11.

The working line is generally the back face of the abutment or end bent and the designated station number is usually on this line. There are also cases where the working line established by the plans for the abutment or endbent is the centerline of bearing and care should always be taken to insure that the working line used in the staking of the structure is correctly identified. It is well to point out that, in the case of a bridge skewed to the roadway, lateral distances from the point line of the pier, end bent, etc., may not be equal and should be noted. This must be taken into consideration when staking the location of piles in the end bent. In the case of cantilever wall abutments, it might be preferable to reference the vertical face of the wall. In all instances, however, guard stakes should be clearly marked to indicate the line used.

The Data Controller can assist the field operation of setting out the working line of abutments and piers by using the ‘Set out line’ program found in the surveying menu. It gives the field party the capability of staking the working line from a point with known coordinates and along a specified bearing. It gives you the flexibility of staking at any distance along the working line that you desire. It has the capability of setting an offset and grade if needed. Refer to the manual that comes with the respective Data Controller for specific information for the use of this program.

It is preferable to establish a benchmark at each end of the bridge at locations as convenient to the bridge as possible and, at the same time, in as safe a location as possible from the construction work area. The fact that these benchmarks must be accurate should be well understood. For convenience, these benchmarks may be transferred to some solid location on the structure at a later date.

Caution should be utilized when staking a structure in a curve. The geometric layout should be closely examined and the Project Engineer and his party chief should be thoroughly familiar with it before staking is started. It may be necessary to prepare a separate sketch by referring to more than one plan sheet to assimilate all the information essential for the correct stakeout. The Project Engineer should be certain he clearly understands whether dimensions are given along the curve or tangent line. Any offsets shown between the centerline or roadway and centerline of bridge should be carefully noted. When calculating dimensions from curve data or transferring from the curve to the tangents, it is imperative that a second party checks all calculations.

**.1432 Checking** - The field layout of every bridge should be thoroughly checked. This check should be made by different survey party from that making the original layout. If possible, a different procedure should be used.

**.1433 Contract Staking** - When "Contract Staking" is included in the contract, the contractor bears full responsibility for his bridge staking. He also has the option of having his layout work checked by some other private engineering firm.

The Project Engineer should check the contractor's bridge layout regardless of what the contractor does in the way of checking. In no event should the Project Engineer's personnel change the contractor's stakes. If a discrepancy exists, it should be resolved before work is allowed to progress.

The contractor may elect to use the Project Engineer's check as his check. While there are no objections to this, it should not be encouraged. The Project Engineer's assumes no responsibility for the bridge layout whether correct or incorrect.

**.1434 Excavation Quantities** - Structures excavation quantities are arrived at similarly to that previously explained for culverts. Refer to Exhibit No. 63-4-11 for field book example.

**.1435 Foundation Preparation and Backfill** – Refer to Specification 603 of the 2000 Standard Specifications for Road and Bridge Construction. When staking a bridge on a project, the engineer and/or his inspector should review project plans and documentation to determine the extent of staking necessary. The pay item of Foundation Preparation is a lump sum item that could and does include a number of construction operations. No staking is necessary for common excavation if the ‘Foundation Preparation’ bid item is listed. Solid rock excavation remains as a pay item and measurement of such should be accomplished. Any undercutting below plan footing elevation due to poor soil or rock should also be measured for payment.

Staking, measurement, and calculations of solid rock excavation, as well as undercutting, is accomplished in the manner outlined earlier in this manual.

## 63-04.1500 ROADWAY GEOMETRY

**.1510 Vertical curves** - All roadway straight-line grades are connected by vertical curves. Vertical curves are provided to insure smooth riding on the pavement, improve appearance and provide safe sight distance for the motorist. All distances along vertical curves are measured horizontally and all offsets from the tangents to the curve are measured vertically. The length of a vertical curve depends on the total change in grade between two straight-line grades and the safe rate of change of grade for the design speed and required sight distance.

A vertical curve is classified symmetrical or non-symmetrical, depending on whether or not it is the same length on both sides of the V.P.I. See Exhibit 63-4-15 for an example of a symmetrical vertical curve.

**.1520 Horizontal Curves** - All roadway alignment consist of:

1. Tangents, or straight sections of roadway, and
2. Curves, which connect tangents.

Perhaps the most basic of all horizontal curves is the simple circular curve. It is also the basis from which all other horizontal curves are developed so a thorough understanding of the simple curve is necessary before one can understand other types of curves. Exhibit 63-4-16 shows an example of a simple circular curve along with definitions of terminology and some properties of the simple curve. Other types of circular curves encountered in highway construction are the compound and reversed curves. The spiral is a special adaptation to a simple curve. See Exhibit 63-4-17 for an example of a spiral curve.

It is suggested that a person interested in more information about these curves obtain a good Route Surveying book.

**.1521 Simple Curve** - An arc of a circle connecting two tangents differing in direction.

**.1522 Compound Curve** - A combination of two or more simple curves in the same direction with a common tangent at the point of junction.

**.1523 Reversed Curve** - A combination of two simple curves of opposite curvature with a common tangent at the point of junction.

**.1524 Spiral Curve** - The spiral curve was first used by railroads but is now in general use in highway alignments. This curve is used as an easement or transition between the tangent and the curve at the P.C. and the curve to the tangent at the P.T. to counter the abrupt change in a simple curve between the tangents and the curve.

## 63-04.1600 SURVEYING EQUIPMENT

**.1610 General** - Surveying instruments are sensitive precision instruments, and as such, need attentive care to retain their accuracy. They are also very expensive and difficult to obtain. A little time spent in cleaning them will minimize down time and repair bills. The equipment is subjected to the worst kind of abuse from dust and moisture which, unless cleaned frequently, will result in excessive wear. Special care in transporting the instrument in a vehicle will avoid knocking the equipment out of adjustment.

All surveying instruments should be checked at frequent intervals to insure maintaining required accuracy. A permanent location for convenient pegging of levels should be established.

It is well to counsel all personnel using surveying instruments to make every effort to prevent damage to these necessary tools. Surveying equipment must never be left unattended. Every means should be exercised to insure the safety of both instruments and personnel while working under conditions of traffic or construction operations.

### .1620 Types of Equipment

#### .1621 The Level

A. The Self-Leveling Level - In the self-leveling type of instrument, an optical system is employed to establish a precise level line of sight. This system replaces the sensitive spirit level bubble used for that purpose in the conventional type Wye and Dumpy Levels. In general, the line of sight is reflected through three prisms within the telescope. The two end prisms are fixed while the middle one is free to swing as a pendulum acting under the force of gravity. So long as the pendulum prisms hangs freely, a level line of sight is maintained regardless of whether or not the telescope tube is truly level.

B. The Hand Level - The Hand Level or, as it is sometimes referred to, the Locke Level, is only used for approximate elevations. It is a metal tube with a plain glass cover at each end with a spirit level, which is fastened to the top of the tube and seen in the left side of the field of view. Some hand levels have telescopic ability, however, most do not. The cross hair is adjusted by two opposing screws.

   The hand level is a versatile piece of equipment and has many uses. The survey party may use one to extend cross-sections in rough terrain. The grade inspector needs one to check on the thickness of the embankment lift. The Project Engineer will find many uses for the hand level such as checking the fall of a drainage ditch or a pipe or making a rough check in any situation where grade or elevations are involved. The hand level is a great time-saver when used correctly, however, it is not considered a precise instrument and should not be used when accuracy is necessary.

**.1622 Leveling Rods** - The rod customarily used by Department construction personnel is the 25-foot fiberglass, telescoping rod. Whether in English (feet/tenths) or metric (meters/centimeters) these rods are extremely useful for all types of level work. Another is the older style Philadelphia rod which is made of wood and extends to 13 feet. Keep the level rods clean as possible, wipe it dry after working in the rain, and oil any screws or sliding parts.

**.1623 Total Station Theodolites** - These instruments incorporate precise angular measurement, both horizontal and vertical, and electronic distance measurement in the same unit. Early models had verniers for angular measurement while later models have digital readouts. These instruments all have optical plumbing. The Department primarily uses the Sokkia SET 5F brand of Total Stations. It has many capabilities as built-in features. Refer to the manual that accompanies the device for the specifics of what it is capable of doing. It works in conjunction with the SDR33 Data Collector to assist the field crews in completing their work in a more timely and efficient manner.

**.1624 Prism & Prism Pole** - Prisms are made of glass and configured in a way to reflect a signal from the total stations for accurately measured distances. They sit on top of a telescoping rod that has a level bubble to assure being plumb and swivel both horizontally and vertically to provide the best signal reflection. You should be aware that most prisms that are purchased by the Department have a –30mm offset called a 'Prism Constant'. The total station <u>must</u> be set to account for this offset or it will read a distance that is 30mm longer that it truly is.

**.1625 SDR33 Electronic Field Book** - The SDR33, also known as a Data Collector, is capable of storing and calculating survey data of virtually all types. The SDR33 Electronic Field Book has the capability of calculating positions based on centerline station and offset throughout the project limits by use of the Roading Program as well as coordinate positions by use of the Topography and Cogo programs. It also has the capabilities of aiding bridge and culvert stakeouts. It is strongly recommended that you become familiar with the operations manual that comes with that SDR33 Data Collector and the basic operations before attempting to establish points in the field for the contractor to work from. As with any tool, it will only do as good a job as the person using it.

A. Roading Program - The horizontal and vertical alignments can be entered directly into the SDR33 Roading Program from information found in the roadway plans. The Roading Program will calculate any position within the project limits without the need of coordinates calculated by other methods. The SDR33 simply needs to be given the station and offset (elevation if needed) that is desired to set out; or after taking a reading on the rod, it can calculate the station and offset (elevation if needed). The information collected or set out can be downloaded to the personal computer to be printed and placed in a bound reference, as described above. This gives the field crew the flexibility to perform surveying operations in a more timely, efficient, and precise manner when collecting borrow site/waste area cross-sections, original ground, or as-built cross-sections; setting out/relocating centerline, right-of-way/temporary easements, etc. The Roading Program also has the capability of generating coordinates for any centerline station and offset that is needed throughout the project limits, as long as the centerline is consistent with the coordinate system established for the project. Refer to Exhibit No. 63-

4-19 for an example project and how to enter horizontal/vertical information into the Roading Program.

B. Topography – This program is used to collect positions on the jobsite and store the coordinates in the SDR33 Data Collector. It is primary used for collecting traverse loop information, cross sections, and other topography information that is needed. Refer to the manual that came with the device for the details of how this program operates.

C. COGO – Set out coords – This program is used to set out positions on the jobsite. These positions are points such as centerline, right of way, etc. that have known coords calculated either by hand or from the designer. Refer to the manual that came with the device for the details of how this program operates.

D. COGO – Set out line – This program is used to set out bearings along a culvert centerline or bridge work lines (abutments and piers). The bearings must start at a point with known coords and can be set out at specified intervals, grade, or offset. Refer to the manual that came with the device for the details of how this program operates.

The SDR33 Electronic Field Book has enough memory to store sufficient data from multiple surveys, without having to be down loaded into a computer, so they can handle a normal days work. Although, it is recommended that information collected throughout a day of fieldwork is downloaded to the personal computer as soon as possible to create a permanent record. All data should be printed and placed in a bound field book as mentioned previously in this chapter. The data can be plotted conventionally by hand or in the electronic file using the CADD program MicroStation.

Coordinate information for the ‘Job’ (the SDR33 considers a ‘Job to be a coordinate file for the project) to be entered into the SDR33 Data Collector may be found in the plans and manually inputted by using the ‘Keyboard input’ program or an electronic file for upload may be available from the designer. If you receive an electronic file from the designer, it should not be taken for granted that everything is correct. You should still check the coordinate geometry for accuracy and verify that the traverse loop in the field has not been disturbed.

.1625 **The Instrument Tripod** - The tripod legs should not be allowed to become loose. The bolts at the head of the tripod should be well tightened against the wood; for example, the proper tension is such that, if one of the tripod legs is raised and allowed to fall of its own weight, it should sink slowly to the ground. The shoes should be examined to see if they are loose. The screws should be set tightly. The points of the shoes should be sharpened whenever necessary. The tripod should be wiped off whenever it gets wet. The tripod cap should be in place whenever the tripod is not in use.

.1626 **The Instrument Box** - The safety of the instrument often depends upon the way it is packed in the box. The rubber cushions underneath the box, the leather straps, buckles, hinges and fasteners should be examined frequently and kept in good condition. The Total Stations should be placed in their case with care. They only fit in the packing one way. If the box does not close easily, the instrument is probably out of position.

.1627 **GPS Surveying Equipment –** This equipment, consisting of a base receiver and a rover receiver, radios, antennas and data collector, utilizes a constellation of satellites orbiting the earth to accurately determine positions on the ground. This type of equipment does not require "line of sight" and can greatly speed up surveying operations. Electronic files, similar to those used in the SDR33, are created and downloaded to the data collector to survey the project.

Currently the Department has one such system and is in the process of purchasing more. At the request of the Project Engineer, this equipment can be used on their projects statewide by calling Central Office Construction at (502) 564-4780.

.1630 **Carrying Instruments** - During fieldwork, levels may be carried on their tripods on the shoulder. The tripod should be held in such a position that the instrument is nearly balanced, but with a slight tendency to fall forward when the tripod is held with one hand. When the instrument with tripod is carried in this position, the instrument can be quickly brought to a vertical position in an emergency, with the tripod on the ground. When carrying an instrument through thick woods or in passing through doorways, it is advisable to put the tripod under the arm, with the instrument in front, so that the one carrying it is better able to protect the same. For transportation in vehicles or whenever the instrument would be in danger if carried on its tripod, it should either be carried in its box or in the arms with one hand under the leveling base. There is always less danger of disturbing the adjustments if the instrument is in its box and properly secured due to its erect position and freedom from shock. The Total Stations must always be carried in the case regardless of the distance.

.1640 **General Instructions for Care and Adjustment** - IMPORTANT - Personnel should know the proper methods of care and adjustment of survey instruments in the field. These instructions, however, are not given with the intent that you should attempt to make repairs or adjustments with which you are not thoroughly acquainted. It is much better to turn the instrument in, when you are in doubt as to the nature of the trouble, with a written, detailed explanation of the trouble in question.

***Under no circumstances should adjustments be attempted on Total Station Theodolites and Electronic Field Books.*** If in doubt as to the instruments' integrity, it should be turned in for adjustment and repair.

Turning the Instrument in for Repairs - In the event it becomes necessary to turn an instrument in for repairs, the Project Engineer should attach an explanation of the malfunction or damage to the instrument. It should also be identified by his name and crew number. He will then contact the District Construction Office relative to his problems with the instrument and request instructions on turning it in.

DO NOT just forget about the instrument once it's sent in for repairs. A periodic check on its availability could aid in seeing that it's returned promptly.

## CHAPTER FOUR

# TYPICAL FIELD BOOK

BOOK 1 OF 10

PCN 07- 1224

~~PROJ. NO. I 64-3(57)95~~

JULY 27, 2007

~~JUNE 17, 1992~~

PULASKI

~~CARTER~~ COUNTY

US 27

L~~EX. CATLETTSBURG R~~D.

C & G BOOK 1 of 1

TYPICAL INDEX

| | |
|---|---|
| ~~TRANSIT BOOK 1 OF 1~~ | ~~PAGE~~ |
| ~~Align & Topo. Sta. 0 to 142~~ | ~~1-70~~ |
| ~~Align. Rev. "A" Sta. 46 to 56~~ | ~~71-80~~ |
| LEVEL BOOK 1 OF 1 | |
| Profile Levels, B.M.'s Sta.1 to 280 | 1-75 |
| Drainage Data | 76-80 |
| CROSS SECTION BOOK 1 OF 2 | |
| X-Sec. & Soundings Sta. 0 to 280 | 1-70 |
| Data on O'head Crossing, Sta. 182+ | 75-77 |
| Levels, X-sect. & Drainage Rev. "A" | 80-93 |
| COMPLETE NOTES BOOK 1 OF 1 | |
| (where all notes are included in one book. | |
| Align. & Topo. Sta. 0 to 52 | 1-15 |
| Profile Levels, B.M.'s Sta. 0 to 52 | 17-28 |
| X-Sect. & Drainage, Sta. 0 to 52. | 30-51 |

<u>NOTE</u>: A complete index of each book should be shown on the flyleaf of said book in a manner similar to the above example.

When the project includes more the one book, a general index of the various books should be show on the flyleaf of Transit Book. NO. 1

Each book no. on the index sheet should show the total no. of books included as: Transit Book 1 of 2(Transit Books) Level Book 2 of 3 (Level Books), etc.

# TYPICAL BENCH OR CHECK LEVEL NOTES

| STA. | + | H. I. | - | ELEV. | | |
|---|---|---|---|---|---|---|
| | | | | | | Date: Page No. Party: |
| | | | | | | Weather: |
| | | | | | | **Note: Show party personnel, date & weather at the beginning of each days work.** |
| BM #1 | 3.08 | 352.52 | | 349.44 | 349.44 | (USGS BM) "X" on NE corner of S. abutment of C & O RR Bridge 200' left of Sta. 1+30 |
| TP | 11.80 | 364.11 | 0.21 | 352.31 | | |
| TP | 12.42 | 375.82 | 0.71 | 363.40 | | |
| BM #2 | | | 4.27 | 371.55 | 371.55 | Spike in root of 24" Oak, 40' rt. Sta. 8+40 |
| TP | 9.22 | 378.73 | 6.31 | 369.51 | | |
| BM #3 | | | 8.96 | 369.77 | 369.77 | Spike in root 3" Sycamore,110' lt. Sta. 14+20 |
| TP | 0.70 | 369.27 | 10.16 | 368.57 | | |
| TP | 0.24 | 357.01 | 12.50 | 356.77 | | |
| TP | 0.98 | 348.58 | 9.41 | 347.60 | | |
| BM #4 | | | 7.36 | 341.22 | 341.22 | "X" on NW corner bottom conc. step front porch of 1 s. brick res. of R.A. White, 70' rt. Sta. 38+65 |

CHECK

349.44
+ 38.44
-46.66
341.22 ✓

38.44 ✓ 46.66 ✓

<u>NEVER ERASE</u>

# TYPICAL LEVEL NOTES

Date: Page No. Party:

Weather:

**Note: Show party personnel, date & weather at the beginning of each days work.**

| STA. | + ROD | H. I. | - ROD | INTER. ROD | ELEV. | | |
|---|---|---|---|---|---|---|---|
| BM #1 | 3.08 | 352.52 | | | 349.44 | USGS B. M. near corner of Court House 27' Rt. Sta. 0 + 40 | |
| 0+00 | | | | 4.8 | 347.7 | | |
| 1 | | | | 5.6 | 346.9 | | |
| + 70 | | | | 4.8 | 347.7 | ℄ East Abut. | |
| + 70 | | | | 12.8 | 339.7 | Edge Water, E. Side Rd'g on solid rock | |
| | | | | 13.2 | 339.3 | ℄ Creek Channel, Rd'g on solid rock | |
| + 89 | | | | 12.8 | 339.7 | Edge Water, W. Side, Rd'g on solid rock | |
| + 89 | | | | 4.8 | 347.7 | ℄ West Abut. | |
| | | | | 8.4 | 344.1 | High Water - 1935(Headwater) | |
| 2 | | | | 5.1 | 347.4 | | |
| + 60 | | | | 4.4 | 348.1 | | |
| 3 | | | | 3.2 | 349.3 | Top of Ridge | |
| 4 | | | | 5.7 | 346.8 | | |
| BM #2 | | | 0.89 | | 351.63 | Nail in root 10" Maple, 60' Lt. Sta. 4+63 | |
| 5 | | | | 4.3 | 348.2 | | |
| TP | 11.8 | 364.11 | 0.21 | | 352.31 | | |
| 6 | | | | 11.2 | 352.9 | | |
| 7 | | | | 9.4 | 354.7 | | |
| + 34 | | | | 8.7 | 355.4 | Bank | |
| + 37 | | | | 11.3 | 352.8 | ℄ Ditch | CHECK ✓ |
| + 40 | | | | 8.3 | 355.8 | Bank | 349.44 ✓ |
| 8 | | | | 7.6 | 356.5 | | +14.88 ✓ |
| 9 | | | | 6.9 | 357.2 | | -0.21 ✓ |
| | 14.88 ✓ | | 0.21 ✓ | | | **NEVER ERASE** | 364.11 |

# TYPICAL PROFILE & CROSS SECTION NOTES

ORIGINAL GROUND

| STA. | + | HI | - | ELEV | CLASS |
|---|---|---|---|---|---|
| BM #1 | 5.26 | 354.70 | | 349.44 | |
| 0 +0 | | | 7 .0 | 347.7 | Earth & Old Asp' Avg. 5' deep to sta. 2+00 |
| 1 +0 | | | 7.8 | 346.9 | |
| + 70 | | | 7 .0 | 347.7 | |
| + 89 | | | 7 .0 | 347.7 | |
| 2+0 | | | 7.2 | 347.5 | 10% S.R. sta. 2+00 to sta. 10+0 |
| TP | 10.84 | 361.90 | 3.64 | 351.06 | |

NOTE:
M=Edge of Metal
F=Fence
E.W.=Edge of Water
S.R.=Solid Rock

Check
349.44
\+ 16.10
\- 3.64

| 16.10 | 361.90 | 3.64 |
|---|---|---|

Date: Page No. Party:
Weather:

Left ℄ Right

USGS BM 27' Lt. Sta. 0+40

| | Left | | | | | ℄ | Right | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 46.4 | 47.0 | 46.5 | 47.4 | | | 47.4 | 46.6 | 47.7 | 48.1 | 48.7 |
| | 8.3 | 7.7 | 8.2 | 7.3 | | | 7.3 | 8.1 | 7.00 | 6.6 | 6 |
| | 30 | 19.5 | 12 | 6 | | | 7 | 13.5 | 15 | 20 | 30 |
| | S.R. | F | | M | | | M | | | F | |
| | 46.8 | 47.0 | 46.0 | 46.1 | | | 46.7 | 46.9 | 46.5 | 47.0 | |
| | 7.9 | 7.7 | 8.7 | 8.00 | | | 8.00 | 7.8 | 8.2 | 7.7 | |
| | 30.5 | 18 | 11 | 5 | | | 7.5 | 12 | 20 | 30 | |
| | | F | | M | | | M | | F | | |
| E. Abut | 46.8 | 47.3 | 47.3 | | | | 47.7 | 47.3 | 45.3 | 42.1 | |
| | 7.9 | 7.4 | 7.4 | | | | 7 | 7.4 | 9.4 | 12.6 | |
| Bridge | 30 | 10 | 7 | | | | 7.5 | 10 | 15 | 30.5 | |
| | | F | M | | | | M | | F | E.W. | |
| W. Abut | 42.1 | 47.4 | 47.1 | | | | 47.7 | 47.4 | 46.5 | 46.1 | |
| Bridge | 12.6 | 7.3 | 7.00 | | | | 7 | 7.3 | 8.3 | 8.6 | |
| | 26 | 10 | 7 | | | | 7 | 10 | 11 | 31 | |
| | | E.W. | | M | | | M | | F | | |
| | 45.0 | 46.7 | 46.4 | 47.1 | | | 47.3 | 46.3 | | | |
| | 9.7 | 8 | 8.3 | 7.3 | | | 7.4 | 8.4 | | | |
| | 30 | 13.5 | 10 | 4 | | | 10 | 17 | | | |
| | S.R. | | M | | | | M | | | | |

*NOTE: Show party, personnel, date & weather at the beginning of each day's work.*

***NEVER ERASE***

# GEODETIC SURVEY MARK PRESERVATION

During the past century and a half, the U.S. Department of Commerce's National Ocean Survey (formerly the Coast and Geodetic Survey) has been determining with great accuracy the latitude and longitude and/or elevation of thousands of locations throughout the United States. At each point a bronze marker is imbedded in cement or bedrock. More than half a million of these markers have been placed in the U.S. and its possessions.

The bronze disks, measuring about three and one-half inches in diameter, mark survey points for latitude and longitude, elevation, gravity, and azimuth or direction. They are used by engineers, surveyors, and mapping agencies as the basis or framework for maps, charts, local control and boundary surveys, and for various public and private engineering projects.

The cost of surveying and placing a single mark ranges from around $100 to several thousand, depending on the type of survey, accuracy, and proximity to other survey monuments.

Resurveying operations throughout the United States have revealed the destruction of an alarming number of permanent survey marks. To remedy this situation as much as possible, NOAA, the National Oceanic and Atmospheric Administration, asks the public's cooperation in preserving these marks.

Many of the marks have been covered with dirt or debris and destroyed because construction crews were not aware of their location. To prevent this, the practice of marking the location of the survey disks with wooden posts set nearby was begun in the 1940's. As these wooden posts deteriorated, metal signs bolted to metal fence posts were later substituted. These white signs, called Witness Posts, are set near survey marks to aid in their recovery and protection.

Here's how the public can help preserve these marks:

Never remove or disturb a survey marker unless authorization is obtained from NOAA. The National Geodetic Survey has a team of Mark Maintenance Engineers who will normally perform the necessary maintenance. If a mark is removed or displaced, its value as a survey point is lost and expensive re-surveying is usually required.

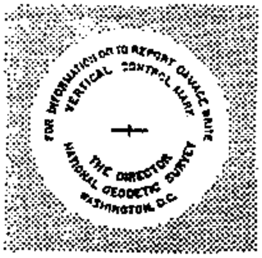
If you see a survey mark which appears in danger of destruction or damage by erosion, construction, or other causes, please take appropriate steps to preserve it. If danger is by construction, call it to the attention of the foreman or flag the mark by stakes.

You will be performing a commendable public service in helping to preserve these valuable survey markers.

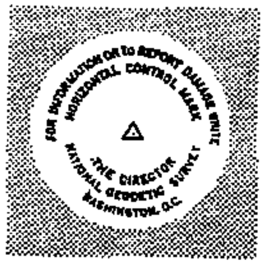
In all cases, submit a report of your actions or finding to Director, National Geodetic Survey, National Oceanic and Atmospheric Administration, Rockville, Maryland, 20852.

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Survey

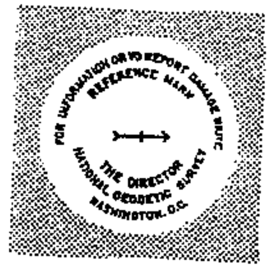
# KNOW THESE MARKS



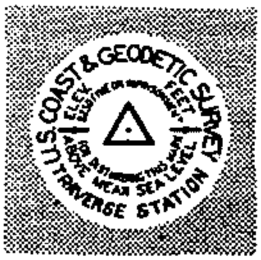
VERTICAL
(NEW)



HORIZONTAL
(NEW)



REFERENCE
(NEW)

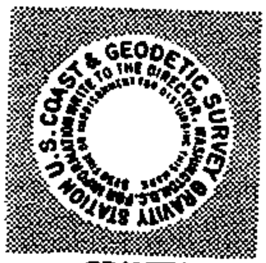


TRAVERSE
(OLD)

TRIANGULATION
(OLD)

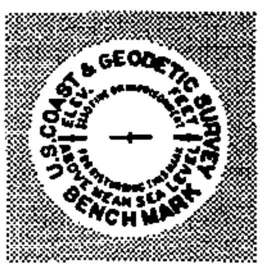
TOPOGRAPHIC
(OLD)

REFERENCE
(OLD)



GRAVITY
(OLD)

AZIMUTH
(OLD)



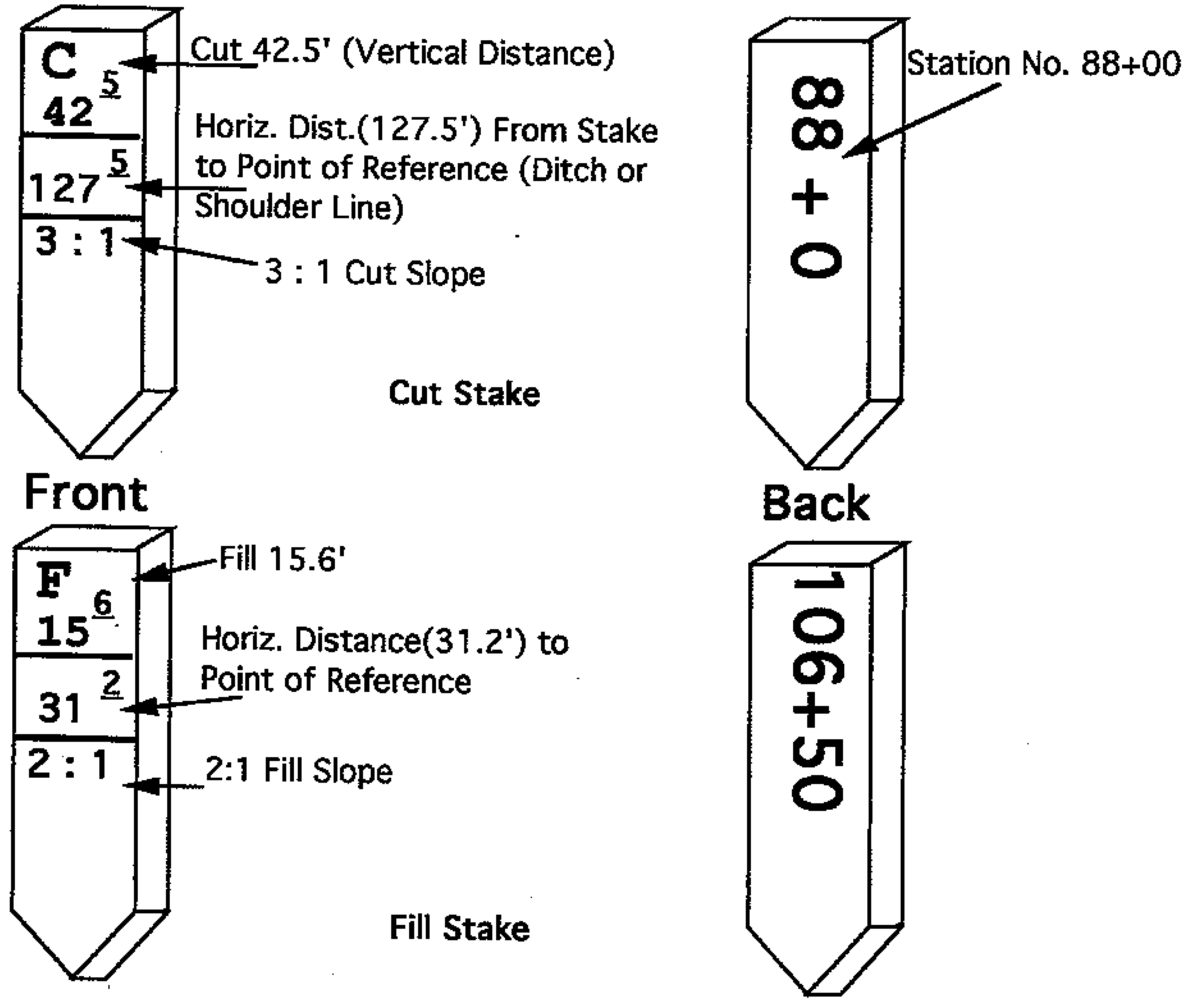
VERTICAL
(OLD)

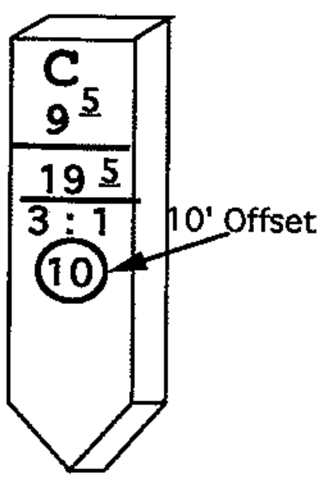
## FACE LEGENDS

Standard bronze station marks of the National Geodetic Survey (formerly marks of the Coast and Geodetic Survey) are set in concrete or bedrock to serve as a permanent mark for the particular station it represents. Additional information concerning these marks may be obtained by writing to:
Director, National Geodetic Survey, NOAA, Rockville, Md., 20852.

NOAA/PA 73022 (Rev.) 1974

# MARKING OF SLOPE STAKES




Offset Slope Stake

General Instructions:

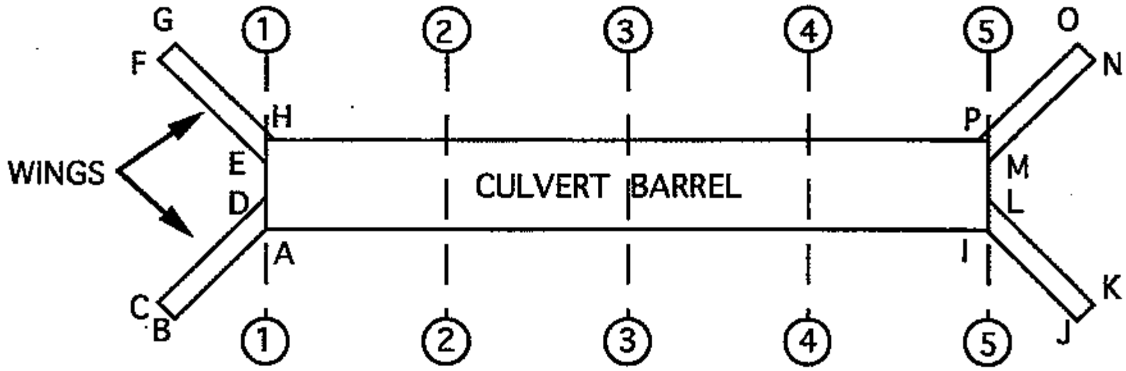
In setting slope stakes, the rod is read to the nearest tenth of a foot and horizontal distances measured, usually with a mettalic tape, at right angles to the survey centerline and recorded also to the nearest tenth of a foot.

Slope stakes shall be driven so that the top of the stake leans away from the centerline for fill stakes and toward the centerline for cut stakes. A standard 1" x 2" x 18" is preferred for use in setting slope stakes.

Use either blue keel or black waterproof marking pen for marking stakes. Data must resist fading or washing off.

# CULVERT CROSS SECTIONS





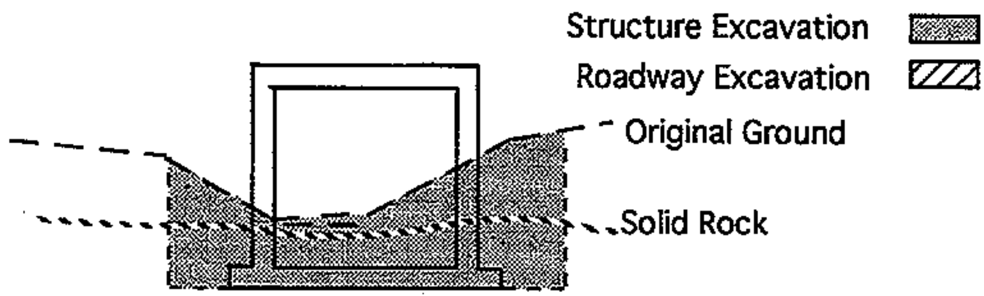

Sketch of example of cross sections for culvert excavation

1. Sections 1 & 5 are taken at limits of excavation at end of culvert parallel with parapets.

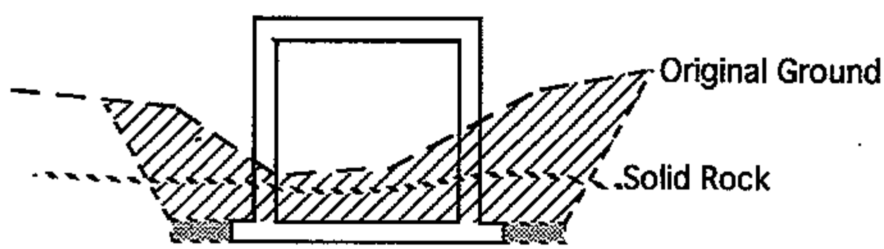
2. Sections 2, 3, & 4 and any other sections needed are taken at necessary intervals to accurately presribe the actual yardage excavated.

3. Letters A thru P show elevations taken at these points to derive an average cut.

4. If it is necessary to plot only the wings to scale when the cross section method is used, it will not be necessary to plot the barrel.




Typical Cross-section where roadway culvert excavation is not involved.

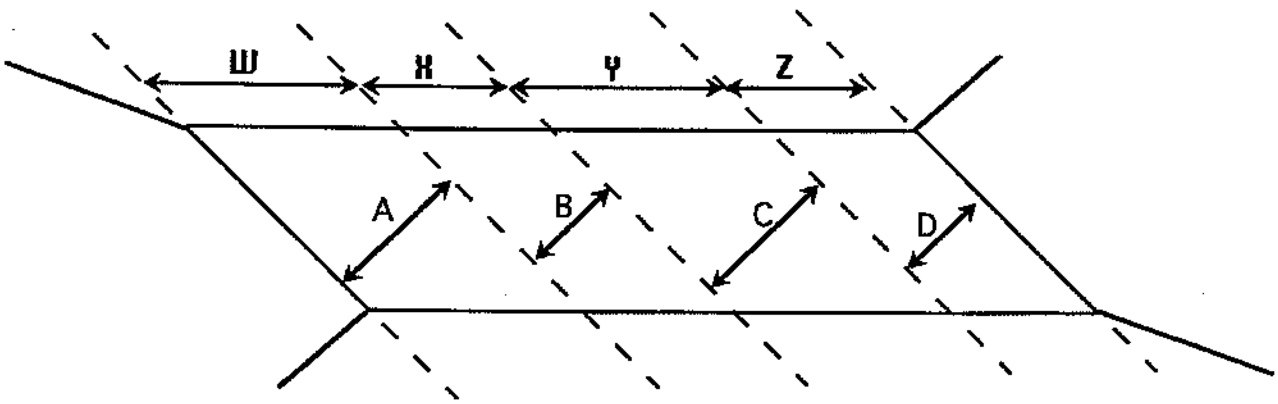



Typical cross-section showing roadway culvert excavation. Whether footer is formed or poured to neat line may be shown in this section.

See Chapter 8 for detailed information on Structure Excavation

# CULVERT CROSS SECTIONS



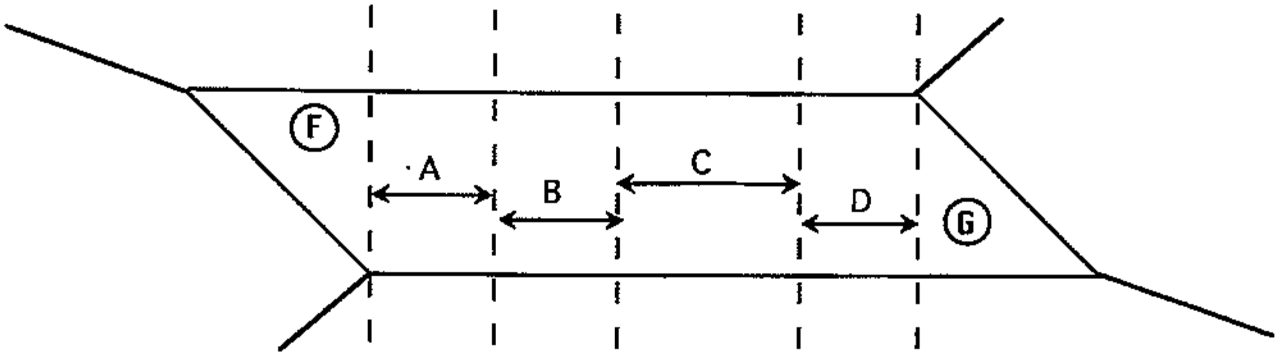



Cross-section method of excavation for skewed culverts

1. Sections taken on same skew as culvert

2. Distances A, B, C, & D are computed by multiplying skewed distance (designated by **W, X, Y & Z** on this sketch) times sine of the angle.

3. Example of this would be a distance of 25 ft. (**W, X, Y or Z**) measured along barrel of culvert on a 30° skew. The actual distance used for computing yardage would be 25 X .86603 (Sine of 30°) or 21.65 ft. (A, B, C or D)




Alternate method of computing yardage on culverts by cross section method.

1. Sections taken at right angles to barrel.

2. Areas F & G computed by average elevation method. These areas areas to be drawn to scale along with wings.

3. The distances between sections (A, B, C, & D) by this method will be measured along the centerline or a line parellel with the centerline of the culvert and the sections will be taken perpendicular to this line.

# FIELD NOTES - CULVERT OUTLET

Sta. 495+77.05 - Const. 4' x 4' x 151'
R. C. Cul. @ 30° Sk. Rt.

Orig. Grd. Elev. Outlet Lt.

℄

| STA. | + | H. I. | - | ELEV. | |
|---|---|---|---|---|---|
| BM #57 | 0.91 | 584.73 | | 583.82 | 583.82 |
| A | | | 12.2 | 572.5 | |
| B | | | 12.6 | 572.1 | |
| C | | | 12.8 | 571.9 | |
| D | | | 12.9 | 571.8 | |
| E | | | 13.1 | 571.6 | |
| F | | | 12.9 | 571.8 | |
| G | | | 12.6 | 572.1 | |
| H | | | 12.5 | 572.2 | |
| I | | | 12.6 | 572.2 | |
| BM #57 | | 584.73 | 0.90 | 583.83 | 583.82 |

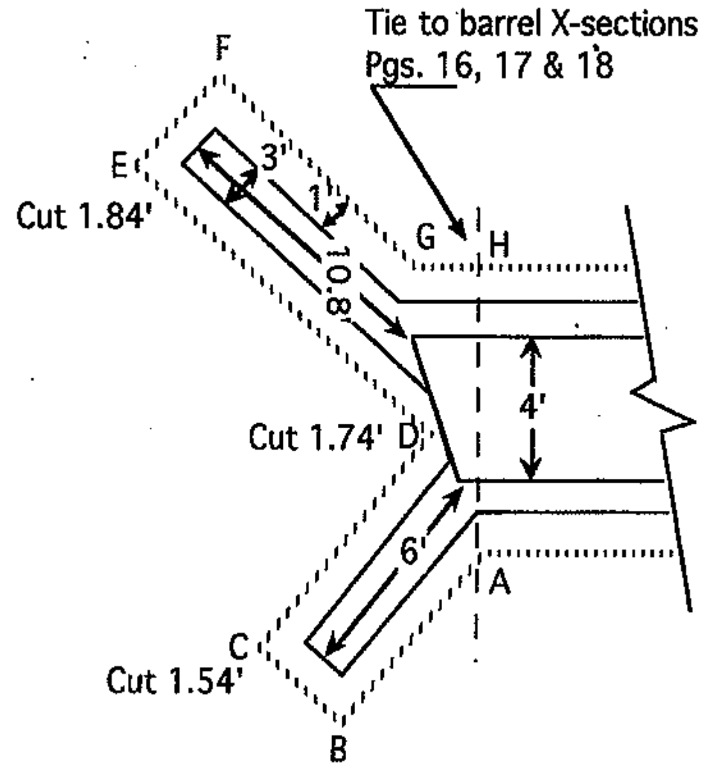
REDUCED C.A.T. 7/25/92
CHK. H.A.M. 7/26/92

7/23/92 Page No. 14
Fair: 68° - 73°

Drawing No. 18813

Bugs - Chief
Jones - ⊼
James - ⊽
Gray - Rod

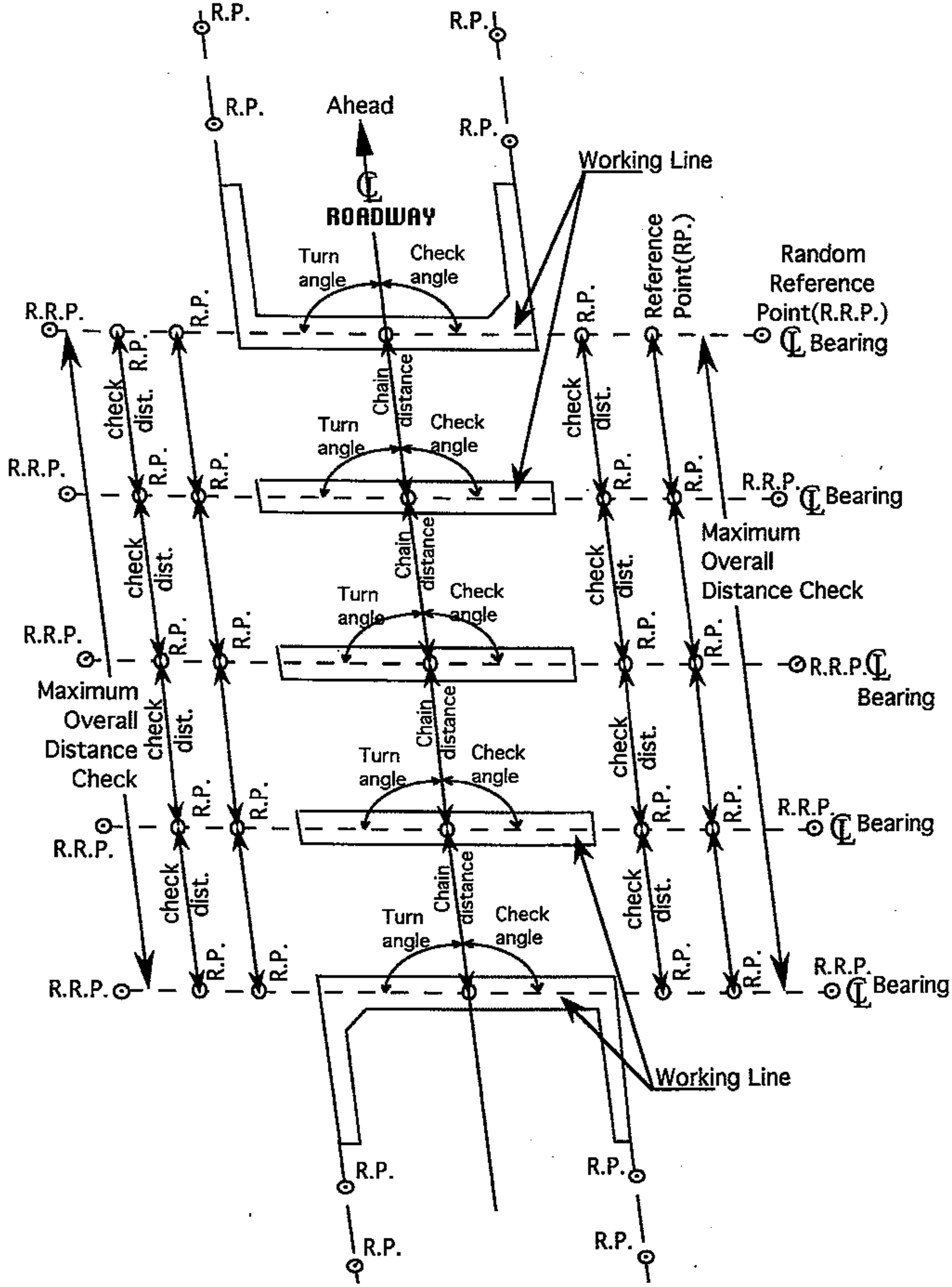
**Note: Show party personnel, date & weather at the beginning of each days work.**




NEVER ERASE

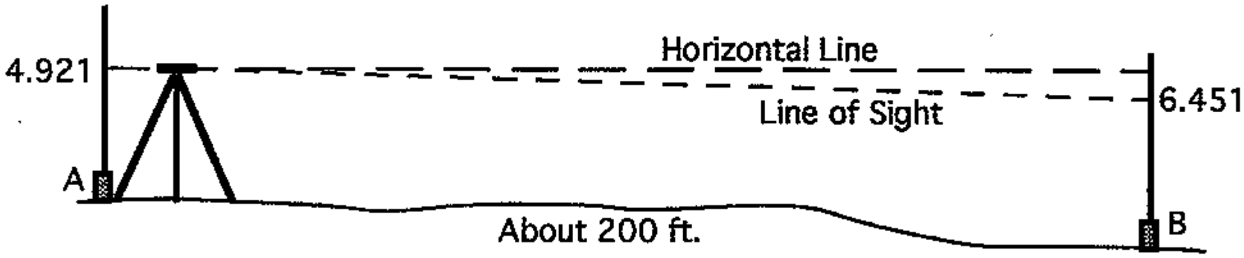
# STRUCTURE LAYOUT





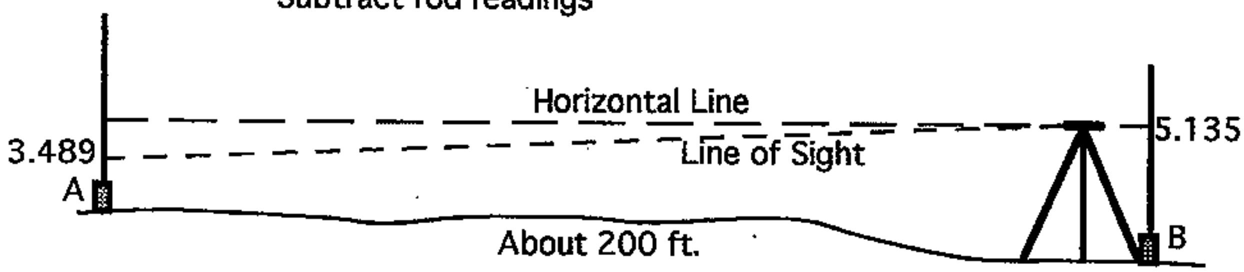
# LEVEL ADJUSTMENT

## TWO PEG METHOD




Difference in Elevation = 6.459 - 4.921 = 1.538

Set two hubs about 200 feet apart
Set up level as near as possible to Point A
Be absolutely certain bubble is centered
Read near rod at Point A through wrong end of level
Read far rod at Point B
Subtract rod readings




Difference in Elevation = 5.135 - 3.489 = 1.646

Repeat Point A procedure at Point B

The true difference in elevation is the average

$$\frac{1.538' + 1.646'}{2} = 1.592'$$

To bring the line of sight to Horizontal:
Leave Level at Point B
Subtract the true difference in elevation from the Point B reading to obtain horizontal reading at Point A

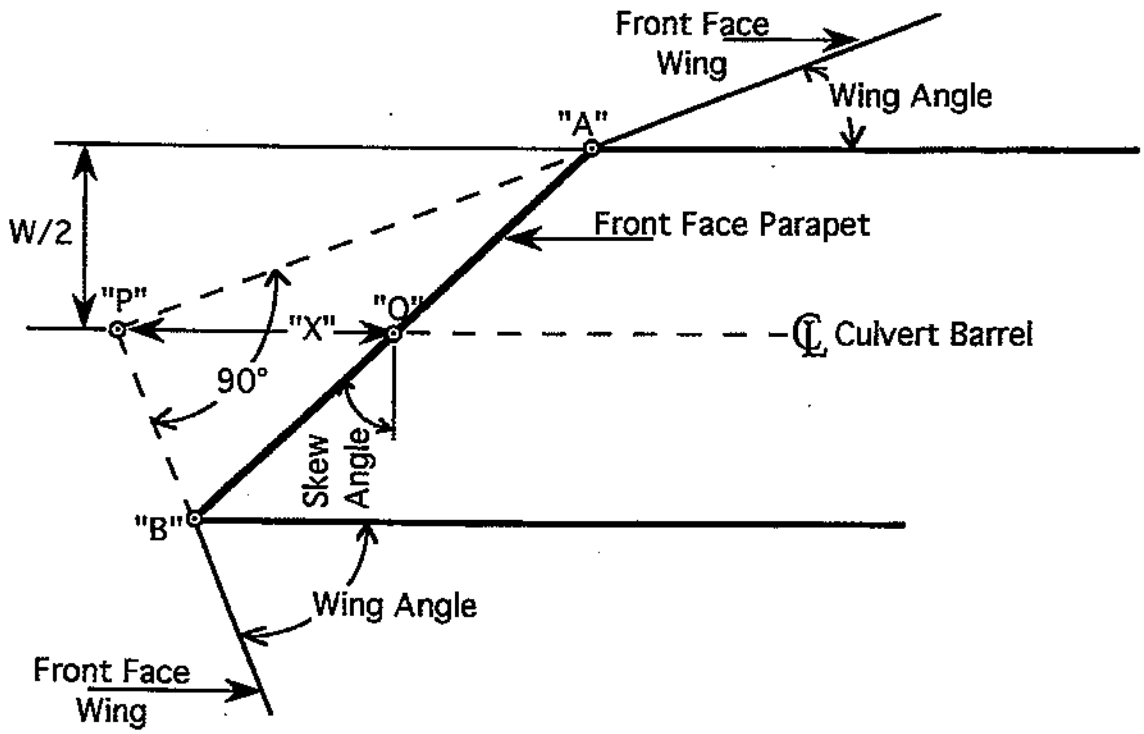
$$5.135 - 1.592 = 3.543'$$

To adjust the Dumpy Level - With the telescope bubble exactly centered, move the cross hairs to read 3.543' at Point A.

To adjust the Wye Level(or a transit) - line the cross hairs on the 3.543 reading on Point A and adjust the bubble tube to show exactly level,

# STAKING CULVERT WINGS

*NOTE: THIS IS A PROCEDURE FOR STAKING CULVERT WINGS WHEN THE WING ANGLES ADD UP TO 90° ONLY.*

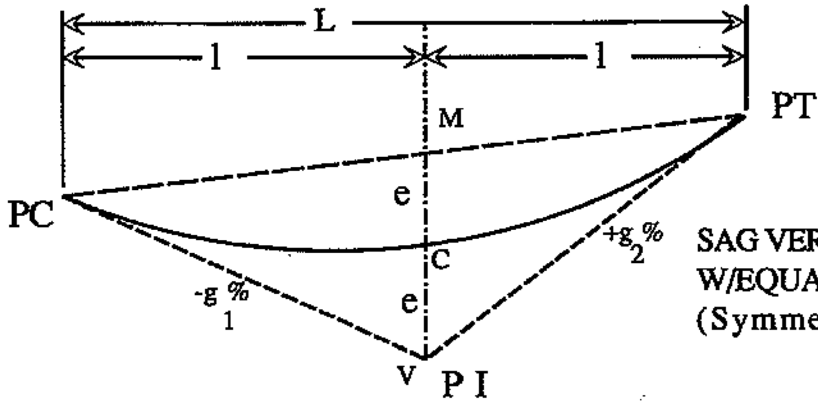



"X" = the distance from the point of intersection of the front face of the parapet and the culvert centerline (point "O") to the projected intersection (point "P") of the wing lines

"X" = (W/2) divided by (Cosine of the Skew Angle)
where "W" = inside width of culvert

Procedure:
(1) Layout points "A", "O", "B", & "P" when staking culvert
(2) Turn wing angles from point "P" and stake wings.
(3) Check - Wing lines must cross points "A" & "B".

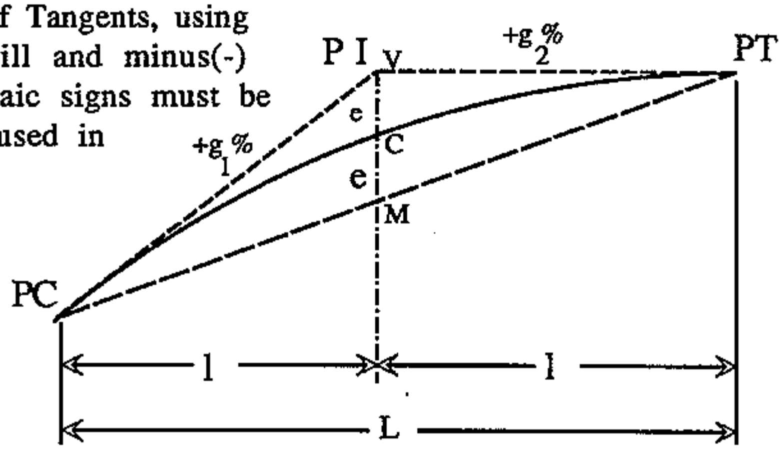
# VERTICAL CURVES




SAG VERTICAL CURVE
W/EQUAL TANGENTS
(Symmetrical)

$g_1$ & $g_2$ = percent grades of Tangents, using plus(+) for grades going uphill and minus(-) for downhill grades. Algerbraic signs must be carried with % grades when used in calculations.

*Drawings are general in nature and not to scale.*




CREST VERTICAL CURVE
W/EQUAL TANGENTS
(Symmetrical)

<u>PROPERTIES OF A SYMMETRICAL VERTICAL CURVE</u>

L = Total length of curve in stations: for example, if L = 400', this curve would be shown on plans as "400 V. C."

l = Length of tangent, both tangents are equal for a symmetrical curve.

e = Vertical offset(ft.) from the Vertex(V), called the P I, to the middle of the curve; e = 1/2 the distance from M to V

P.C. & P.T. = Beginning and ending points of a vertical curve, may be called "V.C." on roadway plans with the elevation shown in feet.

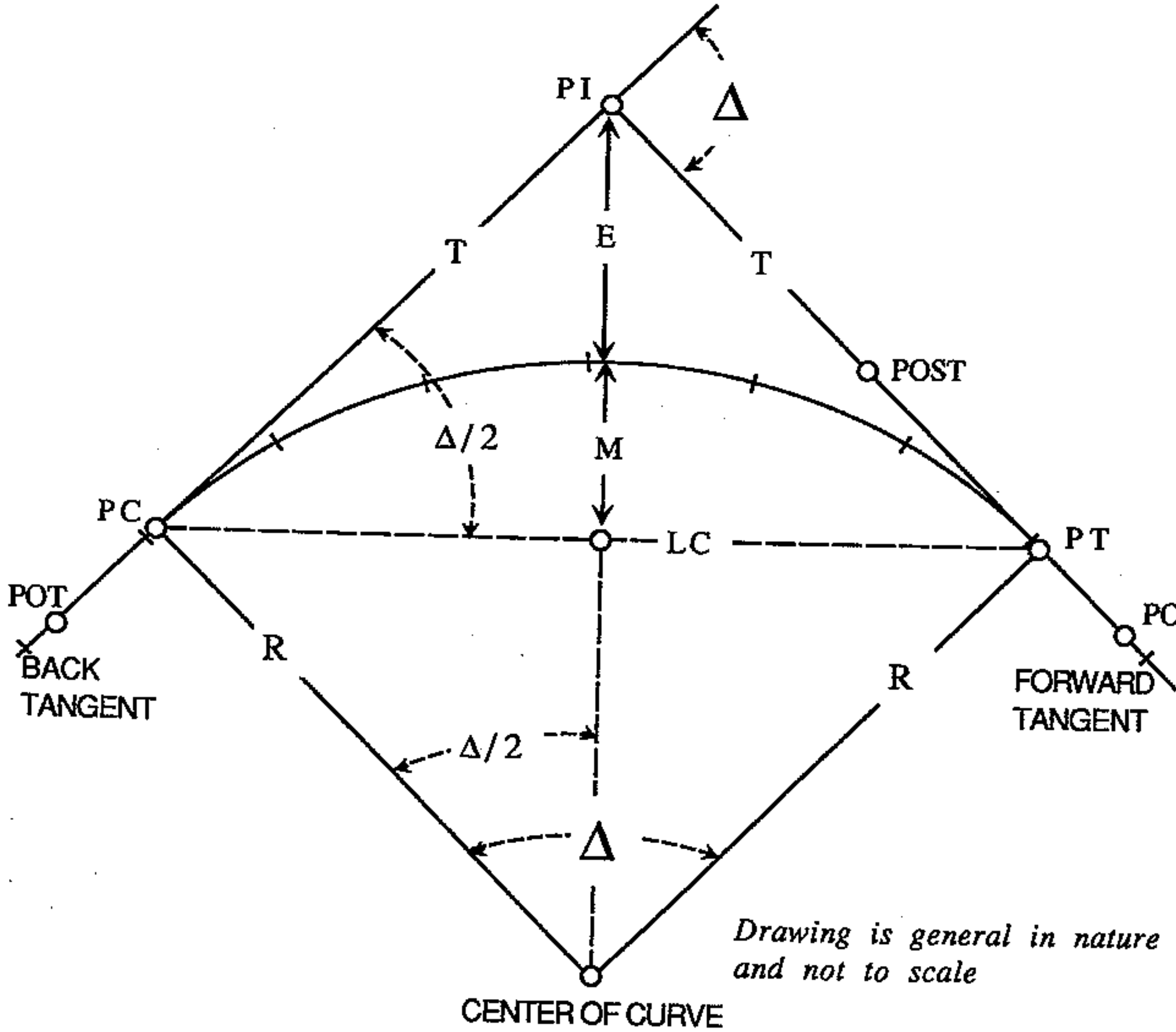
P.I. = Point of intersection of the two straight grades, $g_1$ & $g_2$, usually shown on plans as (P.I.) along with a station no. and elevation

e = Difference in elevation between midpoint(C) of the vertical curve and the P.I. = the distance from (C) to (M), the midpoint of a chord from PC to PT

Sight Distance = Visibility on vertical curves is usually designated on plans as "NPSD" for Non-Pasing Sight Distance or as "HLSD" for Headlight Sight Distance, with the distance shown in feet in both cases.

Unsymmetrical Vertical Curve = This is a vertical curve with unequal tangents. It is rarely encountered and is not discussed herein.

# SIMPLE CIRCULAR CURVE




*Drawing is general in nature and not to scale*

## DEFINITIONS

Simple Circular Curve - An arc of a circle connecting two tangents differing in direction.

P. I. = Point of Intersection - The point where the Back Tangent and the Forward Tangent intersect.

P. C. = Point of Curvature - Point(station) where Back Tangent ends and curve begins.

P. T. = Point of Tangency - Point(station) where curve ends and Forward Tangent starts.

R = Radius - Radius of the curve

T = Tangent - Distance from PC or PT to P I, in a straight line.

E = External - Distance from Middle of Curve to P I

M = Middle Ordinate - Distance to curve from mid point on L C @ 90°

## DEFINITIONS (continued)

L = Length of Curve - Distance around curve from PC to PT.
POT = Point on Tangent - Any point on tangent before the PC(Back Tangent) or after the PT(Forward Tangent)
POST = Point on Sub-Tangent - Any point on tangent between PC and PI or PT and PI
$\Delta$ = Delta Angle - Intersection Angle - Deflection angle between two tangents at the PI
LC = Long Chord - Distance from PC to PT, along a straight line.
D = Degree of Curve - The angle formed by a 100 ft. segment (100 ft. arc) of the curve

## PROPERTIES OF SIMPLE CURVES

Radius - radius of a 1 degree curve = 5730 ft. Radius for any other degree of curve is equal to radius for a 1° curve divided by the degree of curve.

$$\text{Radius for any curve} = \frac{5730 \text{ ft.}}{\text{degree of curve}}$$

$R = \tan 1/2\,\Delta$ $\quad$ $LC = 2 R \sin 1/2\,\Delta$ $\quad$ $M = R - R \cos 1/2\,\Delta$

$L \text{ (in feet)} = \Delta\ /D)\ 100$ $\quad$ $L \text{ (in stations)} = \Delta\ /D$

$D = 100\ \Delta / L$ $\quad$ $D = 5730/R$ $\quad$ $E = (R/\cos 1/2\,\Delta) - R$

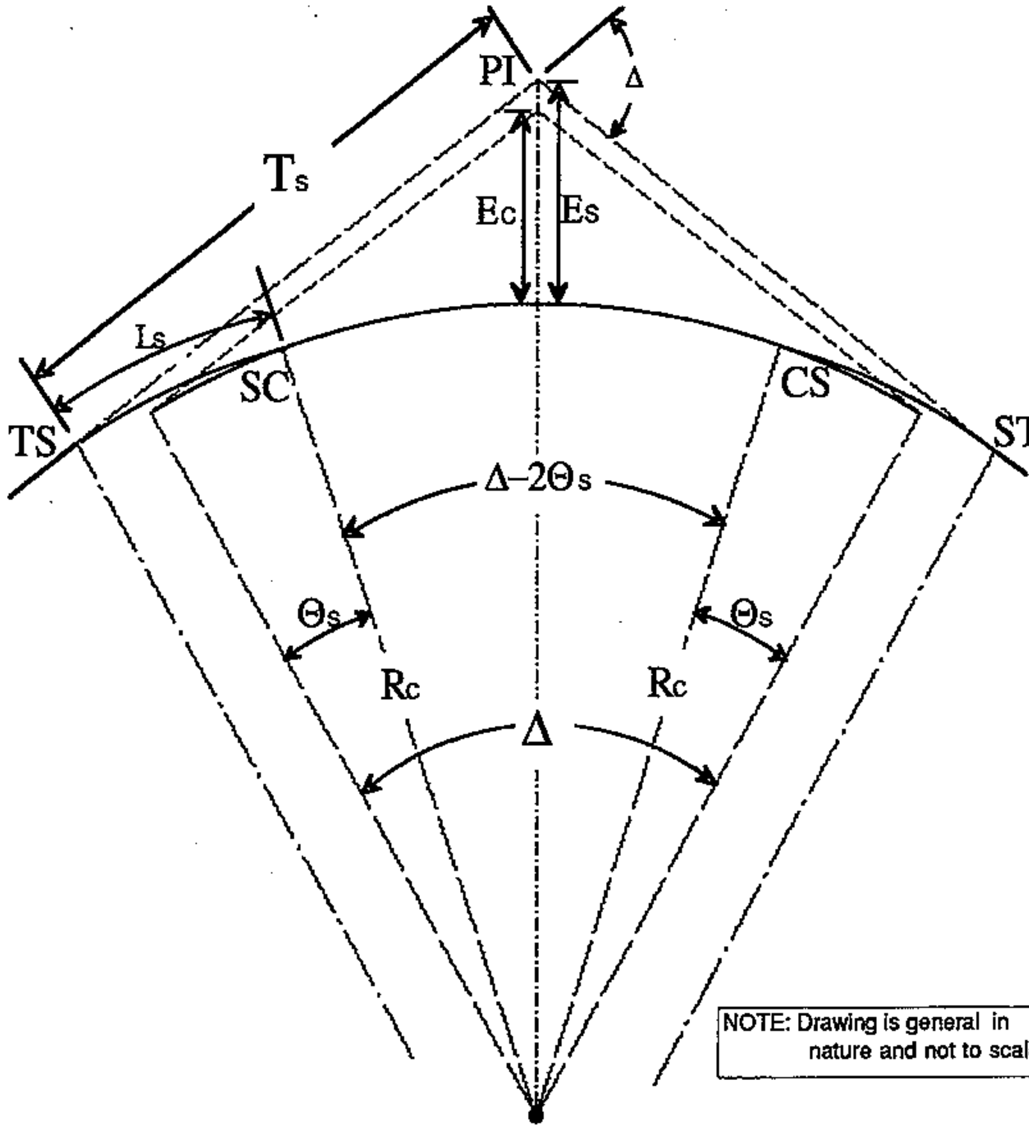
PT Station = PC Station + L $\quad$ PI Station = PC Station + T

Deflection Angle = 1/2 D (for each station of 100 feet)
For a distance of less than 100 ft. on the curve (call it C), calculate the deflection (call it d) as follows:

$$d \text{ (in degrees)} = D/2 \times C/100$$

$$d \text{ (in minutes)} = 0.3\ C\ D$$

# SPIRAL CURVE




NOTE: Drawing is general in nature and not to scale

NOTATIONS AND DEFINITIONS

P. I. ---- Point of intersection of the main tangents
T.S ---- Point of change from tangent to spiral
S.C. ---- Point of change from spiral to circle
C.S. ---- Point of change from circle to spiral
S.T. ---- Point of change from spiral to tangent
R c ---- Radius of the circular curve
L s ---- Length of the spiral curve between T.S. and the S.C.
T s ---- Tangent distance, P.I. to T.S. or S.T.
E s ---- External Distance, P.I. to center of circular curve
Δ —— Intersection angle between main tangents
$\Theta_s$ —— Central angle of spiral arc Ls, called spiral angle
D c ---- Degree of circular curve

## Example of Typical Cogo Input File Typical.cld

*for calculating coordinates and deflections for centerlines*

| | |
|---|---|
| **C L # 1 typical transit notes.** | *Centerline Name* |
| **1 000.00 1 67 00 00 500 10000 50** | *Centerline begining data *** |
| **167.00 11 54 00 4** | *PI Stat., Defl Angle, Deg curve or radius* |
| **456.200** | *End Station* |
| C L # 2 EQUATION 456.200 BK=462.90 AH | *Centerline Name* |
| **2 462.90 1 78 54 00 0 0 50** | *Centerline begining data *** |
| **600.00** | *End Station* |
| **C l # 3 TYPICAL TRANSIT NOTES SPIRAL** | *Centerline Name* |
| **3 000.00 1 18 54 00 0 0 50** | *Centerline Beginning Data *** |
| **988.60 -34 22 00 2.00 200** | *PI Stat., Defle Angle, Deg Curve or radius* |
| **3000.00** | *End Station* |

To Run >> type **STORCL TYPICAL** at C:> prompt (KYCOGO install and in path)

Output files Typical.cll, Typical.clc, Typical.cls, Typical.clp

| | |
|---|---|
| Typical.CLL | centerline output listing (text file to be viewed & printed with word processor) |
| Typical. CLS | centerline Storage |
| Typical.CLC | centerline Coordinates |
| Typical.CLP | centerline PI data for graphic placement |

** Centerline Data Input >> Centerline #, Beginning Station, Quadrant Bearing, Bearing D M S, X coord, Y coord, spacing for Deflection Table

See Section 17 of the KYCOGO manual for more detailed information on input forms and variables used for input.

## Output file Typical.cll (after running STORCL TYPICAL)

*vview file Typical.cll with any word processor (DWA, E88 etc)*

```
======== STORCL Version Jan-17-1991
=========================================
========  Jul-23-1992  11:59 am

  C L # 1 typical transit notes.
  Centerline No. 1  --  P.I.s defined by Station
-----------------------------------------------------------

  P.O.T.    0+00.0000   N 67^00'00.00" E     500.0000  10000.0000   1

-----------------------------------------------------------

  P.I.      1+67.0000                        653.7243  10065.2521   2

  P.C.      0+17.7130   N 67^00'00.00" E     516.3049  10006.9210   3
  P.T.      3+15.2130   N 78^54'00.00" E     800.2186  10093.9931   4

  M.O.C.    1+66.4630                        655.9991  10057.8346   5
  Rad Pt                                    1075.9860   8688.3949   6

                  P.I.  =    1+67.0000
                  Delta =  11^54'00.00" Right
                  C     =   4^00'00.00"
                  T     =     149.2870
                  L     =     297.5000
                  R     =    1432.3945
                  E     =       7.7585

          ------------ Deflection Table ------------

   Instrument at P.C. -- Sta. 0+17.7130
        0+50.0000   0^38'44.67"           32.286     32.286
        1+00.0000   1^38'44.67"           49.997     82.276
        1+50.0000   2^38'44.67"           49.997    132.240
        2+00.0000   3^38'44.67"           49.997    182.164
        2+50.0000   4^38'44.67"           49.997    232.033
        3+00.0000   5^38'44.67"           49.997    281.830
        3+15.2130   5^57'00.00"           15.213    296.966

-----------------------------------------------------------
  P.O.T.    4+56.2000   N 78^54'00.00" E     938.5681  10121.1362   7
```

**Note: take coordinates from Station 4+56.200 above and insert as beginning cooridates of Centerline 2 and Rerun STORCL TYPICAL** *(this will make the coordinates for centerlines 1 & 2 relative to each other)*

======== STORCL Version Jan-17-1991
=====================================
======== Jul-23-1992 11:59 am

C L # 2 EQUATION 456.200 BK = 462.90 AH
Centerline No. 2 -- P.I.s defined by Station

---

| | | | | | |
|---|---|---|---|---|---|
| P.O.T. | 4+62.9000 | N 78^54'00.00" E | .0000 | .0000 | 8 |

---

| | | | | | |
|---|---|---|---|---|---|
| P.O.T. | 6+00.0000 | N 78^54'00.00" E | 134.5352 | 26.3948 | 9 |

```
==========================================
======== STORCL Version Jan-17-1991
==========================================
========  Jul-23-1992  11:59 am

 C l # 3 TYPICAL TRANSIT NOTES SPIRAL
 Centerline No. 3  --  P.I.s defined by Station

--------------------------------------------------------------

P.O.T.    0+00.0000   N 18^54'00.00" E       .0000      .0000   10

--------------------------------------------------------------

P.I.      9+88.6000                     320.2248    935.3000   11

T.S.      0+02.5369   N 18^54'00.00" E       .8218     2.4002   12
S.C.      2+02.5369   N 16^54'00.00" E     63.3959   192.3479   13
C.S.     17+20.8703   N 13^28'00.00" W    108.3501  1692.2993   14
S.T.     19+20.8703   N 15^28'00.00" W     57.2637  1885.6535   15

M.O.C.    9+61.7036                     185.8301    939.3279   16
Rad Pt                               -2677.6731   1025.1483   17

Spiral PI In                            44.0135    128.5529   18
Spiral PI Out                           92.8230   1757.1406   19

                 P.I.  =   9+88.6000
                 Delta =  34^22'00.00" Left
                 C     =  2^00'00.00"
                 Ts    =   986.0631
                 Ls    =   200.0000
                 Lc    =  1518.3333
                 Theta =  2^00'00.00"
                 L.T.  =   133.3418
                 S.T.  =    66.6744
                 R     =  2864.7890
                 Es    =   134.4550

                 x     =   199.9756
                 y     =     2.3269
                 k     =    99.9959
                 p     =      .5818
```

——— Deflection Table ———

Instrument at T.S. – Sta. 0+02.5369

| | | | | |
|---|---|---|---|---|
| 0+50.0000 | -0^02'15.16" | 359^57'44.84" | 47.463 | 47.463 |
| 1+00.0000 | -0^09'29.94" | 359^50'30.06" | 50.000 | 97.463 |
| 1+50.0000 | -0^21'44.72" | 359^38'15.28" | 50.000 | 147.461 |
| 2+00.0000 | -0^38'59.48" | 359^21'00.52" | 50.000 | 197.453 |
| 2+02.5369 | -0^39'59.98" | 359^20'00.02" | 2.537 | 199.989 |

Instrument at S.C. – Sta. 2+02.5369

| | | | | |
|---|---|---|---|---|
| 2+50.0000 | -0^28'28.67" | 359^31'31.33" | 47.463 | 47.463 |
| 3+00.0000 | -0^58'28.67" | 359^01'31.33" | 49.999 | 97.458 |
| 3+50.0000 | -1^28'28.67" | 358^31'31.33" | 49.999 | 147.447 |
| 4+00.0000 | -1^58'28.67" | 358^01'31.33" | 49.999 | 197.424 |
| 4+50.0000 | -2^28'28.67" | 357^31'31.33" | 49.999 | 247.386 |
| 5+00.0000 | -2^58'28.67" | 357^01'31.33" | 49.999 | 297.329 |
| 5+50.0000 | -3^28'28.67" | 356^31'31.33" | 49.999 | 347.250 |
| 6+00.0000 | -3^58'28.67" | 356^01'31.33" | 49.999 | 397.144 |
| 6+50.0000 | -4^28'28.67" | 355^31'31.33" | 49.999 | 447.008 |
| 7+00.0000 | -4^58'28.67" | 355^01'31.33" | 49.999 | 496.838 |
| 7+50.0000 | -5^28'28.67" | 354^31'31.33" | 49.999 | 546.630 |
| 8+00.0000 | -5^58'28.67" | 354^01'31.33" | 49.999 | 596.381 |
| 8+50.0000 | -6^28'28.67" | 353^31'31.33" | 49.999 | 646.086 |
| 9+00.0000 | -6^58'28.67" | 353^01'31.33" | 49.999 | 695.742 |
| 9+50.0000 | -7^28'28.67" | 352^31'31.33" | 49.999 | 745.345 |
| 10+00.0000 | -7^58'28.67" | 352^01'31.33" | 49.999 | 794.891 |
| 10+50.0000 | -8^28'28.67" | 351^31'31.33" | 49.999 | 844.376 |
| 11+00.0000 | -8^58'28.67" | 351^01'31.33" | 49.999 | 893.798 |
| 11+50.0000 | -9^28'28.67" | 350^31'31.33" | 49.999 | 943.151 |
| 12+00.0000 | -9^58'28.67" | 350^01'31.33" | 49.999 | 992.432 |
| 12+50.0000 | -10^28'28.67" | 349^31'31.33" | 49.999 | 1041.638 |
| 13+00.0000 | -10^58'28.67" | 349^01'31.33" | 49.999 | 1090.765 |
| 13+50.0000 | -11^28'28.67" | 348^31'31.33" | 49.999 | 1139.808 |
| 14+00.0000 | -11^58'28.67" | 348^01'31.33" | 49.999 | 1188.765 |
| 14+50.0000 | -12^28'28.67" | 347^31'31.33" | 49.999 | 1237.631 |
| 15+00.0000 | -12^58'28.67" | 347^01'31.33" | 49.999 | 1286.403 |
| 15+50.0000 | -13^28'28.67" | 346^31'31.33" | 49.999 | 1335.076 |
| 16+00.0000 | -13^58'28.67" | 346^01'31.33" | 49.999 | 1383.649 |
| 16+50.0000 | -14^28'28.67" | 345^31'31.33" | 49.999 | 1432.115 |
| 17+00.0000 | -14^58'28.67" | 345^01'31.33" | 49.999 | 1480.473 |
| 17+20.8703 | -15^11'00.00" | 344^49'00.00" | 20.870 | 1500.625 |

Instrument at S.T. – Sta. 19+20.8703

| | | | |
|---|---|---|---|
| 17+20.8703 | 0^39'59.98" | .000 | 199.989 |
| 17+50.0000 | 0^29'11.79" | 29.130 | 170.865 |
| 18+00.0000 | 0^14'36.58" | 50.000 | 120.869 |
| 18+50.0000 | 0^05'01.36" | 50.000 | 70.870 |
| 19+00.0000 | 0^00'26.13" | 50.000 | 20.870 |

---

P.O.T. 30+00.0000 N 15^28'00.00" W -230.5161 2925.7034 20